

Spectroscopic Measurements of Hydrogen Ion Temperature During Divertor Recombination

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INTRODUCTION

- Objective: measure T_i in divertor plasma,
- Use D_α spectrum observed by Fabry-Perot interferometer,
- For recombining regions:
 - Spectrum characterized by n_e and T_i ,
 - Emissions dominated by recombination,
 - \Rightarrow can fit to determine n_e , T_i .
 - Can get independent n_e and T_e high n Balmer lines.
- But,
 - Chord covers range of n_e , T_i ,
 - Other processes do contribute,
 - \Rightarrow need to simulate spectrum to validate interpretation.
- Here: demonstrate using DEGAS 2 with UEDGE C-Mod plasma.



BACKGROUND

- Radiative timescales \ll collision timescales
⇒ emissions do reflect T_i .
- Recombination D_α emission dominates excitation for $T_e \sim 1$ eV or less,
 - Can minimize contributions from other physical processes.
- Doppler and Stark widths comparable here,
 - Have to fit Voigt profile.



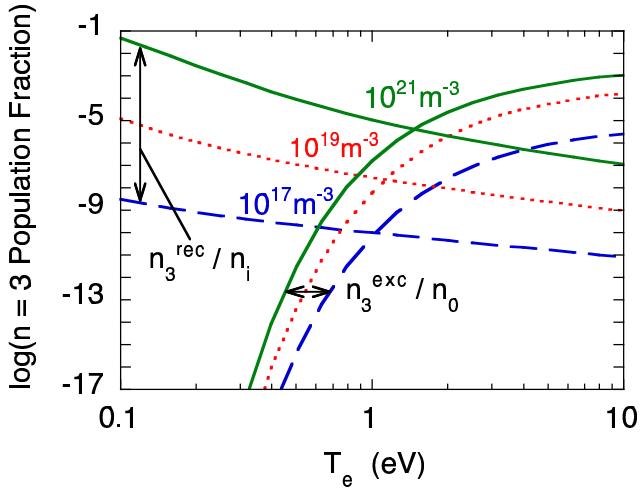


Figure 1: Fractional density of the $n = 3$ excited state due to excitation of the ground state hydrogen atom (per ground state atom) and due to recombination (per ion).

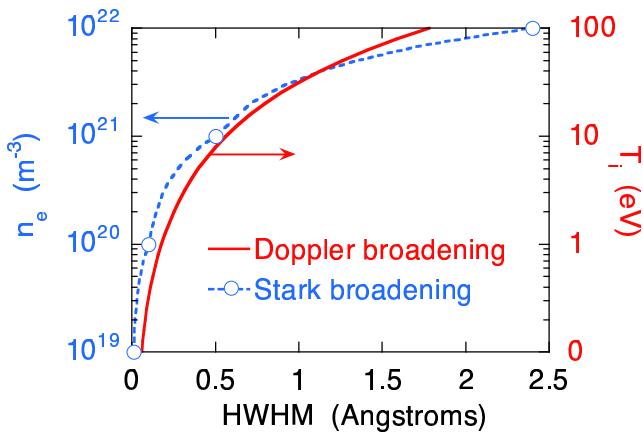


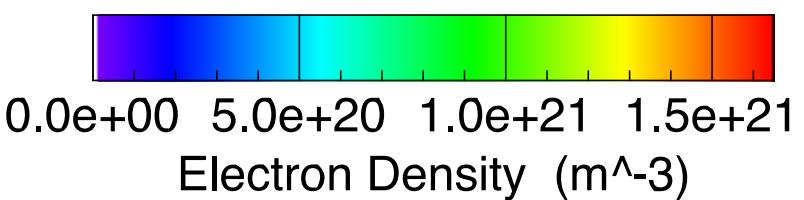
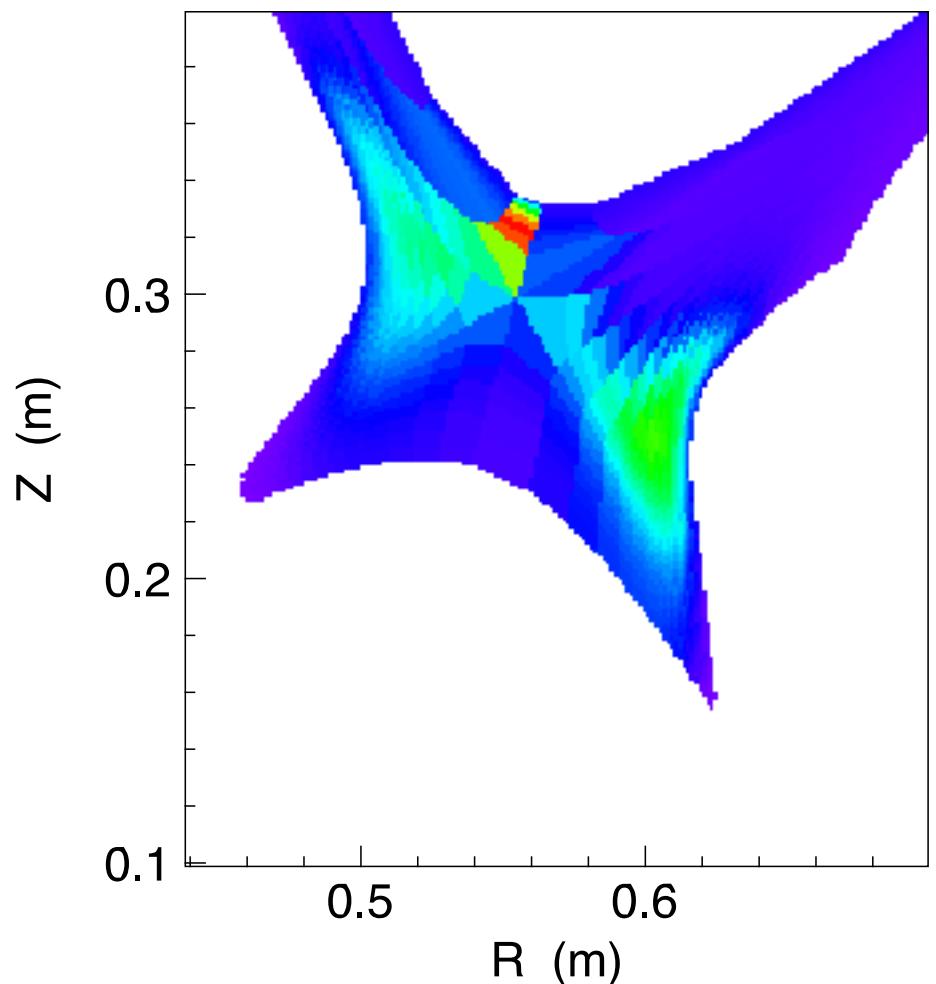
Figure 2: Half-width of Balmer- α line at half-maximum (HWHM) as generated by Stark (left scale, electron density) and Doppler (right scale, ion temperature) broadening. The Stark width curve is a linear interpolation between data points (the open circles) taken from Oza (1988).



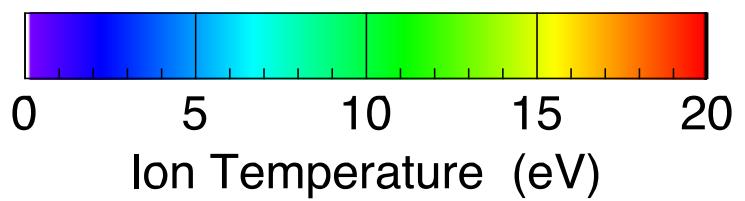
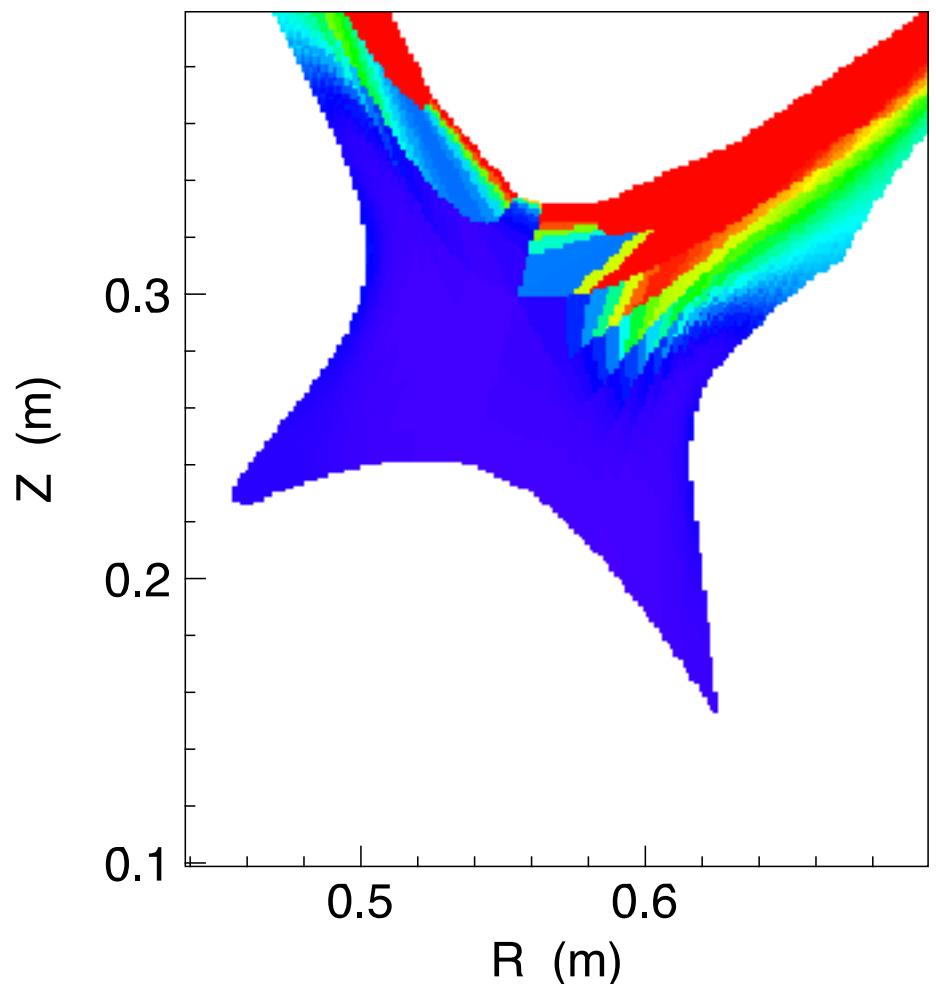
SIMULATION OF D _{α} SPECTRUM

- Input to DEGAS 2: detached C-Mod UEDGE plasma from Wising,
 - Recombination sink \sim current to targets,
 - Large recombination peaks.
- Simulate spectrum on two chords,
 1. 50% recombination,
 2. 92% recombination,

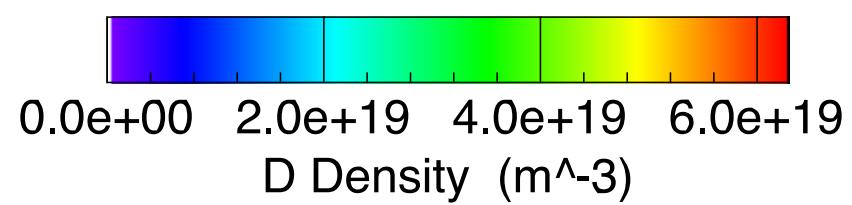
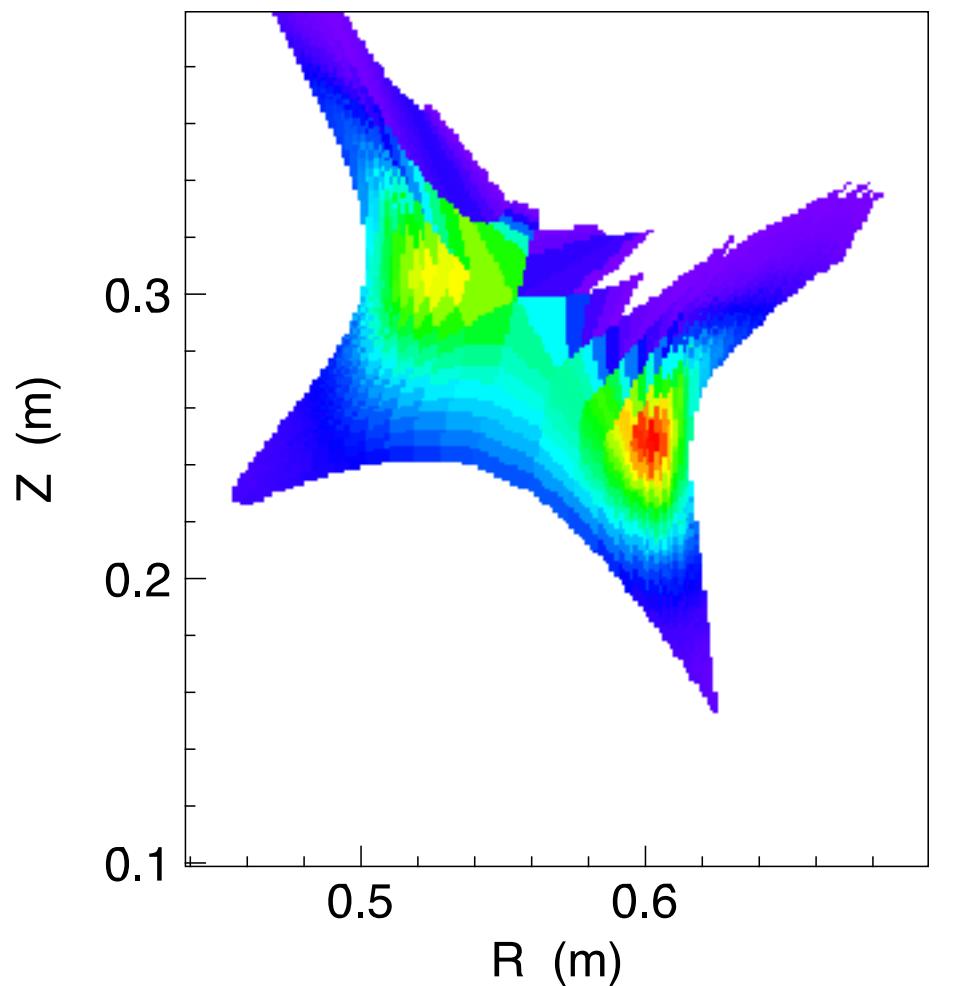




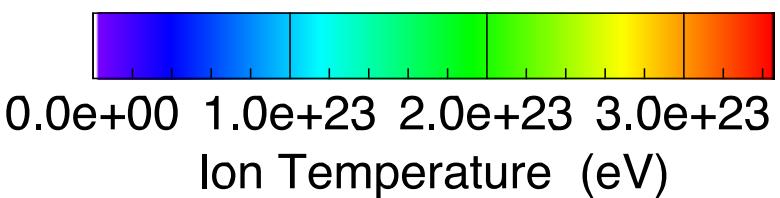
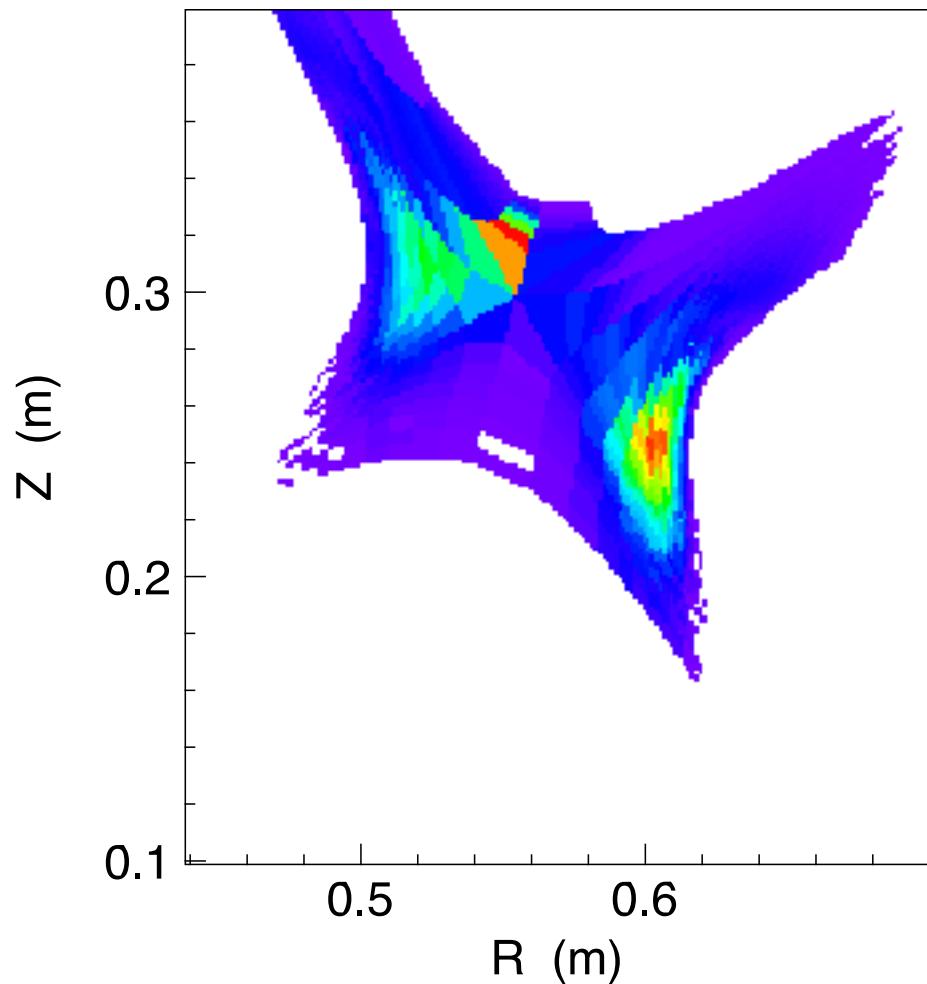
electron_density vs. (row, col)



ion_temperature vs. (row, col)



spD_density_0604_rev vs. (row, col)



H_alpha_rate_rev vs. (row, col)

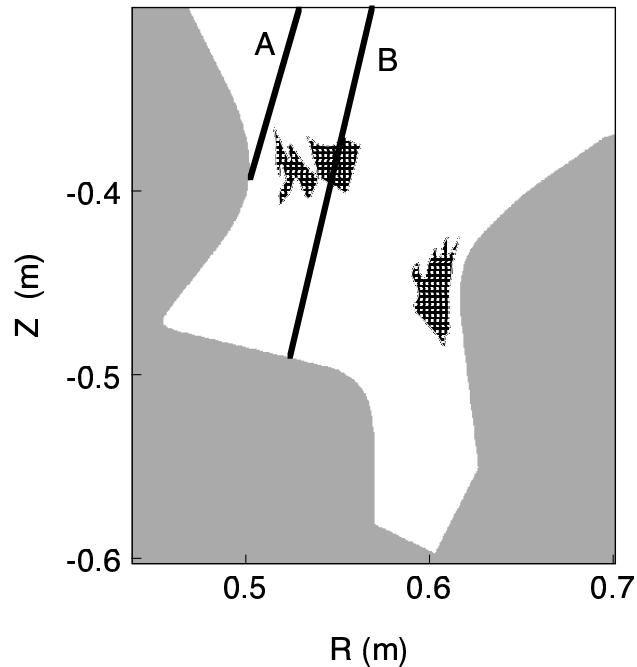


Figure 3: The chords labeled “A” and “B” are used to simulate the D_α spectrum. The shaded region corresponds to the material surfaces in Alcator C-Mod. The irregularly shaped cross-hatched regions have a D_α emission rate exceeding 10^{23} photons / m^3 .

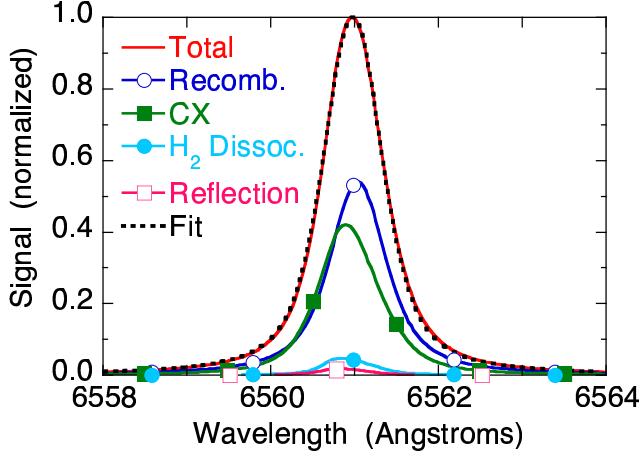


Figure 4: Simulated spectrum along chord A. The total signal is normalized to a peak value of unity. The separate contributions to the total made by each physical process, normalized by the same factor, are included. The “Fit” curve is a Voigt profile corresponding to $n_e = 4.2 \times 10^{20} \text{ m}^{-3}$ and $T_i = 2.3 \text{ eV}$.

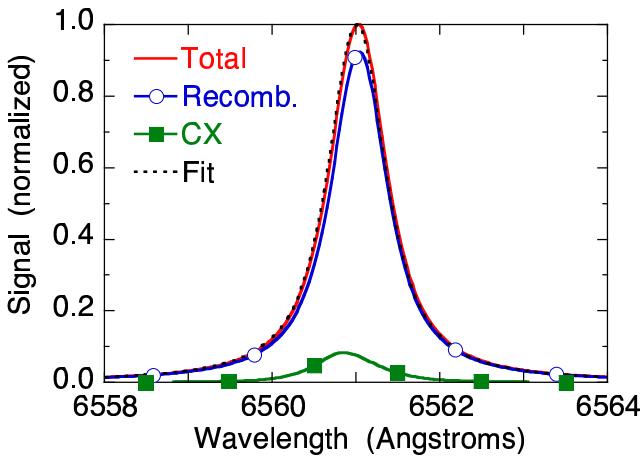


Figure 5: Simulated spectrum along chord B. The total signal is normalized to a peak value of unity. The separate contributions to the total made by recombination and charge exchange, normalized by the same factor, are included. The “Fit” curve is a Voigt profile corresponding to $n_e = 6.6 \times 10^{20} \text{ m}^{-3}$ and $T_i = 0.81 \text{ eV}$.

FITTING PROCEDURE

- Fit total and recombination spectrum,
 - Later provides a more accurate benchmark of method.
- Vary both n_e and T_i ,
 - Shift line center as needed,
 - Fits robust to changes in
 - * Number of points,
 - * Weighting factors,
 - * Initial guesses.
- Compare with $\langle n_e \rangle$, $\langle T_i \rangle$:
 - Volume average weighted by D_α and chord path.



	Chord 1			Chord 2		
	Input	Recomb.	Total	Input	Recomb.	Total
$n_e (10^{20} \text{ m}^{-3})$	4.	5.0	4.2	6.6	6.8	6.6
$T_i (\text{eV})$	3.2	1.4	2.3	1.5	0.60	0.81

Table 1: Fit results (for both the total spectrum and the portion due to recombination) and corresponding plasma parameters input to the simulation

DISCUSSION

- Differences in table entries underscore need for interpretation of fits,
- Temperature variations under investigation,
 - Single point simulation does yield right answer!
 - Next: look at few point runs.



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